

Test Report For:
SPIG Industries, LLC
SGET End Terminal



TESTED TO:
Manual for Assessing Safety Hardware (MASH 2016)
Test 3-31

PREPARED FOR:
SPIG Industries, LLC
14675 Industrial Park Road
Bristol, Virginia 24202

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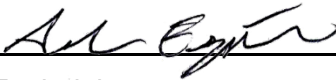


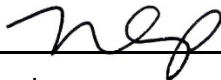
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16. Abstract <p>One (1) Test Level 3, Test 31 (3-31) was performed on the subject SPIG Industries, LLC SGET end terminal. The terminal was impacted by a 2012 RAM 1500 4-door pickup truck. Testing was conducted by KARCO Engineering, LLC. in Adelanto, CA on June 8, 2018.</p> <p>The test vehicle impacted the SGET end terminal at a velocity of 62.53 mph (100.63 km/h) and an impact angle of 0.6°. The vehicle forced the impact head down the rail and allowed the vehicle to exit to the traffic side. The system brought the vehicle to a stop in a controlled manner. The system was damaged from post 1 through post 7.</p> <p>The test vehicle sustained damage to its front end and passenger side. The front bumper and frame rails were damaged. The passenger front wheel broke off the vehicle. The occupant compartment was not penetrated and the deformation limits were not exceeded.</p> <p>The SPIG Industries, LLC SGET met all the requirements for MASH 2016 Test 3-31.</p>			
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Quantity	Typical Application	Std Units	Metric Unit	Multiply By
Mass	Vehicle Weight	lb	kg	0.4536
Linear Velocity	Impact Velocity	miles/hr	km/hr	1.609344
Length or Distance	Measurements	in	mm	25.4
Volume	Fuel Systems	gal	liter	3.785
Volume	Small Fluids	oz	mL	29.574
Pressure	Tire Pressures	lbf/in ²	kPa	6.895
Temperature	General Use	°F	°C	=(Tf -32)/1.8
Force	Dynamic Forces	lbf	N	4.448
Moment	Torque	lbf-ft	N•m	1.355

1. Introduction

1.1 Problem Statement

The purpose of this report is to detail the safety performance of the SPIG Industries, LLC Spig Gating End Terminal (SGET) when evaluated to the criteria set forth by *Manual for Assessing Safety Hardware* (MASH 2016).

1.2 Objective

The primary objective of this project was to evaluate the safety performance of the SGET when subjected to full-scale crash testing according to MASH 2016 Test Level 3, Test 31 (3-31) for redirective terminals.

1.3 Scope

This project consists of full-scale dynamic crash testing of the SGET end terminal. The system was subject to MASH 2016 Test 3-31. Test 3-31 was conducted with a 2270P test vehicle impacting the system at a nominal angle of 0° with the centerline of the vehicle aligned with the centerline of the terminal.

2. System Details

2.1 Test Article

The SPIG Gating End Terminal (SGET) is an energy absorbing guardrail end treatment designed to reduce the severity of end on impacts with W-beam guardrail. When impacted the SGET feeds the rail through the impact head and exits to the non-traffic side of the system. The SGET system was composed of one (1) impact head, one (1) post 1 assembly, one (1) cable anchor system, one (1) specialty panel, and seven (7) yielding posts. The posts were spaced 75.0 in. (1.9 m) on centers with the rail splices located at the posts. The total terminal length was 50.0 ft. (15.2 m). The system was attached to 106.3 ft. (32.4 m) of standard guardrail with splices placed midspan. The system can be installed with a top rail height of 31 in. \pm 1 inch. The as-tested system was installed with a rail height of 30.0 in. (762 mm) to increase the risk of vehicle override. The system was tested with an RFID chip attached to the impact head.

The impact head rests over the specialty panel and mounts to the first post with two (2) 3.0 in. (76 mm) long lag bolts and washers. The impact head was 64.0 in. (1.6 m) long and had a rear chute width of 5.0 in. (127 mm). The front face of the impact head was 24.0 in. (610 mm) tall and 17.0 in. (432 mm) wide. Welded 9.0 in. (229 mm) behind the front face of the impact head was a 0.625 in. (16 mm) thick steel post breaker plate. The chute was composed of 0.25 in. (6 mm) C-channel. The downstream end of the impact head tapers to an overall height of 13.5 in. (343 mm). There were two (2) 0.5 in. (13 mm) thick straps welded at the downstream end of the impact head.

Post 1 was a wooden post inserted into a steel foundation tube and once assembled was 8.9 ft. (2.7 m) long. The wooden post and foundation tube were connected with a 10.0 in. (254 mm) long 0.625 in. hex head bolt. The steel foundation tube was 6.0 in (152 mm) by 8.0 in. (203 mm) and 6.0 ft. (1.8 m) long. The wooden portion of post 1 was a 5.5 in. (140 mm) by 7.5 in. (188 mm) and was 4.2 ft. (1.3 m) long. The wooden portion had two (2) 0.75 in. (19 mm) holes drilled 13.0 in. (330 mm) down from the top to mount the strike plate and block. The strike plate and block were installed on the leading side of post 1 with one (1) 14.0 in. long 0.625 in. guardrail bolt, washer and guardrail nut. The rail does not attach to post 1 and there is no blockout.

The cable anchor assembly was secured to post 1 with a bearing plate and to the specialty panel with a guardrail grabber. The cable was routed through a 2.5 in (64 mm) hole located at the base of post 1. The bearing plate was 0.625 in (16 mm) thick and had two (2) 0.5 in. (13 mm) holes at the top used to secure the plate to post 1 with two (2) lag bolts. The downstream end of the cable assembly was the guardrail grabber. The grabber was 17.0 in. (432 mm) long and had

six (6) teeth that lock into the specialty panel. Between the specialty panel and the grabber there was a 17.0 in. (432mm) long reinforcement panel. The reinforcement panel was held onto the rail with six (6) 1.0 in long 1/2 in. bolts, twelve (12) washers, six (6) lock washers and six (6) nuts. The specialty panel was a standard 12 Ga w-beam section measuring 12.5 ft. (3.8 m) long and had six (6) rectangular slots cut for the guardrail grabber. The other three (3) panels in the terminal section were standard 12 Ga 12.5 ft. (3.8m) MGS guardrail panels.

Posts 2 through 8 were 6.0 ft. (1.8 m) long yielding posts. The yielding posts had two (2) 0.5 in. (13 mm) holes drilled through both of its flanges 31.0 in. (787 mm) from the top of the post. There was a 3.0 in. (76 mm) by 3.0 in. (76 mm) by 80.0 in. (2032 mm) long strut channel that was connected between post 1 and 2. The upstream end was mounted at the connection point of the foundation tube and wooden post. The downstream end of the strut was connected to post 2 with two (2) 2.0 in. long 1.5 in. bolts, four (4) washers, 2 lock washers and two (2) nuts. Post 2 attached to the specialty panel with a standard 1.25 in. long 0.625 in. guardrail bolt and nut with no blockout. Posts 3 through 8 used 8.0 in. (203 mm) deep notched wooden blockouts and 10.0 in. long 0.625 in. guardrail bolts.

After the terminal there was one (1) 9.4 ft. (2.9 m) panel to transition the splices to the midspan location. After the transition panel there were seventeen (17) W6x8.5 galvanized steel posts, seventeen (17) 8.0 in. (203 mm) deep notched wooden blocks and six (6) 12.5 ft. (3.8 m) MGS panels. The rails were spliced together with 1.25 in. long 5/8 in. guardrail splice bolts and nuts. The rails were held to the posts using 10.0 in. long 5/8 in. guardrail bolts and nuts. A second 9.4 ft. (2.9 m) transition panel was used before the downstream anchor and the installation was terminated with an SFT type anchor.

Photographs of the as-tested unit and installation are available in Appendix A of this report. The manufacturer's drawings are available in Appendix D. A complete set of manufacturer drawings are available in KARCO CD-R 2022-6716.

3. Test Requirements and Evaluation Criteria

3.1 Test Requirements

The SGET system described in this report was classified as a redirective terminal. MASH 2016 recommends a series of up to nine (9) full scale crash tests to evaluate redirective terminals. However, Test 3-36 is intended for a system that had a rigid backup structure and is not applicable for this system. Test 3-38 is intended for a staging device and is not applicable for this system. Therefore Test 3-36 and 3-38 were not conducted.

Table 1 MASH 2016 TL-3 Test Matrix for Redirective Terminals

	Test Designation	Impact Conditions			Evaluation Criteria
	MASH Test No.	Vehicle	Nominal Speed (mph)	Nominal Angle (deg)	
Test Level 3	3-30	1100C	62	0	C,D,F,H,I,N
	3-31	2270P	62	0	C,D,F,H,I,N
	3-32	1100C	62	5-15	C,D,F,H,I,N
	3-33	2270P	62	5-15	C,D,F,H,I,N
	3-34	1100C	62	15	C,D,F,H,I,N
	3-35	2270P	62	25	A,D,F,H,I
	3-36	2270P	62	25	A,D,F,H,I
	3-37a	2270P	62	25	C,D,F,H,I,N
	3-37b	1100C			
	3-38	1500A	62	0	C,D,F,H,I,N

3.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three criteria: (1) Structural Adequacy, (2) Occupant Risk, and (3) Post-Impact Vehicular Response. Criteria for structural adequacy evaluate the article’s ability to allow redirection, controlled penetration, or controlled stopping of the vehicle. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Post-impact vehicular response is a measure of the potential of the vehicle to result in a secondary collision with other vehicles or fixed objects.

Post-Impact Head Deceleration (PHD), Theoretical Head Impact Velocity (THIV), and Acceleration Severity Index (ASI) occupant risk values have also been calculated for the evaluation of the crash tests.

Table 2 MASH 2016 Evaluation Criteria for Terminals and Crash Cushions

Evaluation Factors	Evaluation Criteria			
Structural Adequacy	C	Acceptable test article performance may be by redirection, controlled penetration, or controlled stopping of the vehicle.		
Occupant Risk	D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment or present undue hazard to other traffic, pedestrian, or personnel in a work zone.		
	F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees		
	H.	Occupant impact velocities (OIV) should satisfy the following		
		Occupant Impact Velocity Limits, ft/s (m/s)		
		Component	Preferred	Maximum
	Longitudinal and Lateral	30 ft/s (9.1 m/s)	40 ft/s (12.2 m/s)	
	I.	The occupant ridedown acceleration should satisfy the following limits		
Occupant Ridedown Acceleration Limits (G)				
Component		Preferred	Maximum	
Longitudinal and Lateral	15.0 G	20.49 G		
Post-Impact Vehicular Response	N.	Vehicle trajectory behind the test article is acceptable.		

3.3 Soil Strength Requirements

In accordance to Appendix B of MASH 2016, the soil strength must be verified before any full-scale crash testing can be conducted on soil-based installations. Two instrumented W6x16 posts are installed near the impact area of the installation. The posts are pulled prior to full-scale testing to ensure the soil meets 90% of the established baseline.

4. Test Conditions

4.1 Test Facility

This test series was conducted at KARCO Engineering's test facility in Adelanto, California.

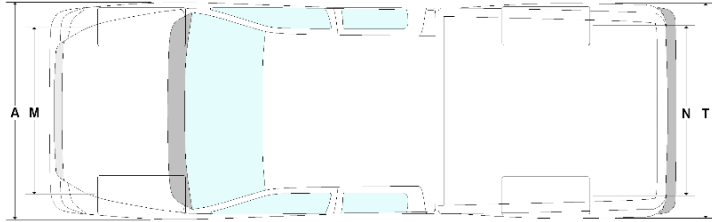
4.2 Vehicle Tow and Guidance System

The tow road is a continuous level surface constructed of reinforced concrete and measures 700.0 ft. (213.4 m) in length, 14.0 ft. (4.3 m) wide, and 6.0 in. (152 mm) thick. A steel rail is embedded in the road to provide vehicle guidance. Vehicle tow propulsion is provided by a 1 ton truck using a 1-to-2 pulley system. The test vehicle is towed into the test article by a nylon rope clamped to a 0.375 in. (10 mm) steel cable. The clamp is released from the cable on contact with a cable release mechanism positioned to allow the test vehicle to proceed under its own momentum for a maximum of 25.0 ft. (7.6 m) before impacting the test article.

4.3 Test Vehicles

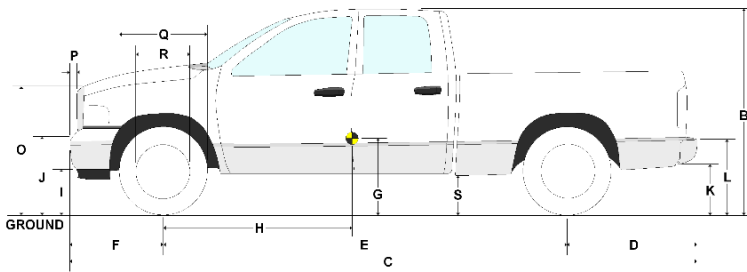
For test 3-31, an 2270P test vehicle was used. The vehicle was a 2012 RAM 1500 4-door pickup truck with a front mounted engine, automatic transmission, and rear wheel drive. The 2270P test vehicle had a curb and test inertial weight of 5,080.5 lbs (2,304.5 kg) and 4,989.0 lbs (2,263.0 kg), respectively. An Anthropomorphic Test Device (ATD) was not used for this test. The test vehicle information can be found in Figure 1.

Test Date..... 06/08/18 Project No..... P38108-01 Year..... 2012
 Make..... RAM Model..... 1500 Color..... White
 Tire Size..... P265/70R17 Vehicle Vin #..... 1C6RD6FP7CS278235
 Tire Inflation..... 40 psi Odometer..... 129,383 mi



GVWR Rating

Total..... 6,700 lbs
 Front..... 3,700 lbs
 Rear..... 3,900 lbs



Engine Type..... V8
 Engine Size..... 4.7 L
 Transmission Type..... Automatic
 Dummy Type..... None
 Dummy Mass..... N/A
 Seat Position..... N/A

Previous Vehicle Damage.... Cosmetic damage

No.	Inches	mm	No.	Inches	mm	No.	Inches	mm	No.	Inches	mm
A	78.9	2003	F	38.7	982	K	19.2	488	P	4.8	122
B	74.7	1897	G	28.5	724	L	29.1	740	Q	30.7	780
C	227.8	5787	H	64.2	1631	M	67.5	1715	R	18.3	465
D	48.4	1230	I	13.4	340	N	67.7	1720	S	13.7	348
E	140.7	3575	J	24.6	625	O	45.7	1160	T	79.6	2023

TEST VEHICLE MASS

	As Received (lbs)			Test Inertial (lbs)			Gross Static (lbs)		
	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total
Left	1448.4	1100.1	2548.5	1310.6	1138.7	2449.3	1310.6	1138.7	2449.3
Right	1444.0	1088.0	2532.0	1402.1	1137.6	2539.7	1402.1	1137.6	2539.7
Ratio (%)	56.9	43.1	100.0	54.4	45.6	100.0	54.4	45.6	100.0
Total	2892.4	2188.1	5080.5	2712.7	2276.3	4989.0	2712.7	2276.3	4989.0

	As Received (kg)			Test Inertial (kg)			Gross Static (kg)		
	Front	Rear	Total	Front	Rear	Total	Front	Rear	Total
Left	657.0	499.0	1156.0	594.5	516.5	1111.0	594.5	516.5	1111.0
Right	655.0	493.5	1148.5	636.0	516.0	1152.0	636.0	516.0	1152.0
Ratio (%)	56.9	43.1	100.0	54.4	45.6	100.0	54.4	45.6	100.0
Total	1312.0	992.5	2304.5	1230.5	1032.5	2263.0	1230.5	1032.5	2263.0

Figure 1 Test 3-31 Vehicle Information

4.4 Data Acquisition Systems

All data acquisition for this test of the terminal was performed in accordance with the MASH 2016 requirements.

4.4.1 Test Vehicle Instrumentation

The test vehicle was instrumented with one (1) tri-axial accelerometer and one (1) tri-axial angular rate sensor. The set of accelerometers and angular rate sensors were mounted within 2.0 in. (50 mm) of the test vehicle's center of gravity in the x-y plane. The accelerometers measured longitudinal (x), lateral (y), and vertical (z) acceleration. The angular rate sensors measured roll (moment x), pitch (moment y) and yaw (moment z).

Table 3 Vehicle Instrumentation List for Test 3-31

Ch.	Location	Axis	Ident. No.	Description	MFR	Model	Units
1	Vehicle CG	X	P51708	Accel, Half Bridge	Endevco	7264-2K	g
2	Vehicle CG	Y	P51700	Accel, Half Bridge	Endevco	7264-2K	g
3	Vehicle CG	Z	P51696	Accel, Half Bridge	Endevco	7264-2K	g
4	Vehicle CG	Yaw	ARS8537	Rate Gyro	DTS	ARS-18K	Deg/s
5	Vehicle CG	Pitch	ARS8532	Rate Gyro	DTS	ARS-18K	Deg/s
6	Vehicle CG	Roll	ARS8486	Rate Gyro	DTS	ARS-18K	Deg/s

4.4.2 Calibration

All instrumentation used in this test has been calibrated through standards traceable to NIST and is maintained in a calibrated condition.

4.4.3 Photographic Documentation

Photographic documentation of this test series included a minimum of two (2) real-time video cameras at 30 frames per second (fps), and six (6) high-speed color digital video cameras at 1,000 fps. All high-speed cameras were activated by a pressure-sensitive tape switch which was positioned on the test article to indicate the instant of contact (time zero). A digital still camera was used for documenting the pre- and post-test condition of the test article and the test vehicle.

Table 4 High Speed Camera Information Test 3-31

View No.	Location	Identification No.	Manufacturer	Type
1	Driver Overall View	7959	Phantom	V9
2	Passenger Overall View	6657	Phantom	V10
3	Inline Track View	8187	Phantom	V10
4	Overhead Close-up View	6710	Phantom	V5.1
5	Overhead Overall View	6075	Phantom	V10
6	Oblique View	8520	Phantom	V10

4.4.4 Measurement Uncertainty

Measurement uncertainties have been determined for pertinent values affecting the results of this test. KARCO maintains these uncertainty budgets, which are available upon request, but are not included in this report. In certain cases the nature of the test method may preclude rigorous and statistically valid calculation of uncertainty of measurement. In these cases KARCO attempts to identify the components of uncertainty and make a reasonable estimation. Reasonable estimation is based on knowledge of the performance of the method and on the measurement scope and makes use of, for example, previous experience and validation data.

5. Crash Test Results

5.1 Static Soil Test

Prior to full scale crash test P38108-01, a static soil test was conducted to ensure the soil condition was acceptable for full-scale crash testing. The static test results at 5.0 in. (127 mm), 10.0 in. (254 mm) and 15.0 in. (381 mm) were above 90% of the baseline established during soil certification. Static test results can be found in Appendix C of this test report.

5.2 Weather conditions

Test No. P38108-01 was conducted on June 8, 2018 at approximately 11:12 A.M.

Table 5 Weather Conditions Test 3-31

Temperature	81 °F
Humidity	18%
Wind Speed	2 mph
Wind Direction	North

Information for reference only

5.3 MASH 2016 Test 3-31

As recommended in MASH 2016 a full-scale impact test was conducted to evaluate the impact performance of the Spig Industries, LLC SGET end terminal to MASH Test 3-31 on June 8, 2018. The test article was positioned at an angle of 0° to the direction of travel of the test vehicle, with the vehicle centerline aligned with the centerline of the terminal. The test was conducted using a commercially available 2012 RAM 1500 4-door pickup truck with a test inertial mass of 4,989.0 lbs (2,263.0 kg).

5.4 Test Description

The test vehicle impacted the system at a velocity of 62.53 mph (100.63 km/h) and an angle of 0.6°. The vehicle's centerline was set to impact the center of post 1, the actual first point of contact with the system was 1.2 in. (30 mm) from the center of post 1. Upon impact the vehicle begins to push the impact head down the first rail. The post breaker contacts the strike plate at 0.015 s and the post fractures at its base. The rear strap contacts the guardrail grabber at 0.029 s and disengaged it from the rail. While the grabber was disengaging from the rail it impacted post 2 causing the post to pull from the rail. The downstream end of the impact head contacts the wooden blocks at posts 3 through 5 at 0.123 s, 0.210 s, and 0.309 s, respectively. The contact with the impact head caused the wooden blocks to fracture and the post bolt to pull from the rail.

When the downstream end of the impact head passed post 5 an elbow began to form in the W-beam. The rail buckled at the chute and the impact head was perpendicular to the vehicle at 0.382 s. After the rail buckled the vehicle began to exit to the traffic side of the system. The passenger side front tire was punctured at approximately 0.500 s. As the vehicle gated through the system the impact head damaged the passenger side of the vehicle.

The vehicle lost contact with the system rotating about its yaw axis. The vehicle came to rest 58.4 ft. (17.8 m) downstream and 15.4 ft. (4.7 m) left from its initial point of contact with the system measured from the vehicle's center of gravity.

5.5 Test Article Damage

The system was damaged from post 1 through post 8. The first rail and the majority of rail 2 were fed through the impact head. The wooden portion of post 1 was broken at its base. Post 2 through 6 were bent at the ground line and activated the breakaway holes. Post 7 disengaged from the rail and post 8 remained attached to the rail. The front face of the impact head was deformed. The reinforcement panel remained attached to the first rail and was flatted with the rail. The guardrail grabber had a slight tear at its upstream end.

5.6 Test Vehicle Damage

The vehicle's damage was concentrated at its front end and passenger side. The front bumper was deformed at its center and the frame rails were bent inward. The radiator was crushed and pushed rearward into the engine. The front passenger side spindle was broken and caused the wheel to detach from the vehicle. The passenger side quarter panel and its support were deformed. Both passenger side doors and the bed side were deformed. The occupant compartment was not penetrated and the deformation limits were not exceeded.

Table 6 Maximum Occupant Compartment Deformation by Location

Location	Maximum Deformation	MASH Allowable Deformation
Roof	0.0 in.	4.0 in. (102 mm)
Windshield	0.0 in.	3.0 in. (76 mm)
Window	0.0 in.	0.0 in
Wheel / foot well and toe pan	0.3 in. (8 mm)	9.0 in. (229 mm)
Side front panel (forward of A-pillar	0.0 in.	12.0 in. (305 mm)
Front side door area (above seat)	0.0 in.	9.0 in. (229 mm)
Front side door area (below seat	0.0 in.	12.0 in. (305 mm)
Floor pan and transmission tunnel	0.3 in. (8 mm)	12.0 in. (305 mm)

5.7 Structural Adequacy

Acceptable test article performance may be by redirection, controlled penetration, or controlled stopping of the vehicle. The test article brought the vehicle to a controlled stop.

5.8 Occupant Risk

Under occupant risk, the test articles are evaluated by four (4) criteria. The first criterion evaluates the potential hazard of detached elements, fragments, or other debris from the test article to penetrate the test vehicle's occupant compartment or present undue hazard to other traffic, pedestrians, or personnel in a work zone. The second criterion is that the vehicle remains upright. The third criterion is that the roll angle of the vehicle does not exceed 75° throughout the test. The final criteria are based on the calculated Occupant Impact Velocities (OIV) and occupant ridedown accelerations. The maximum allowable limit for Occupant Impact Velocity Limit in both the longitudinal and lateral directions is 40.0 ft/s (12.2 m/s). The maximum allowable ridedown acceleration in both the longitudinal and lateral directions is 20.49 g. Both criteria are calculated from the acceleration data collected during the test.

The maximum extent of the debris field was 49.6 ft. (15.1 m) downstream and 18.2 ft. (5.5 m) to the field side measured from the first point of contact with the system. The debris consisted of broken blockouts, the cable assembly, and the upper portion of post 1.

Table 7 Summary of Occupant Risk Factors

Test Parameter	Axis	Units	Max	Time (ms)	Min	Time (ms)
Vehicle Impact Velocity	X	ft/s	91.5			
Occupant Impact Velocity	X	ft/s	18.4	190.4		
Occupant Impact Velocity	Y	ft/s	1.3	190.4		
Ridedown Acceleration	X	g	3.2	639.3	-6.0	775.7
Ridedown Acceleration	Y	g	2.7	738.1	-4.4	607.2
THIV		ft/s	18.7	191.6		
PHD		g	6.0	775.8		
ASI			0.54	25.0		
Roll	X	deg.	12.0	999.9	-4.7	806.0
Pitch	Y	deg.	1.4	508.5	-6.4	995.4
Yaw	Z	deg.	0.0	3.0	-29.6	796.5

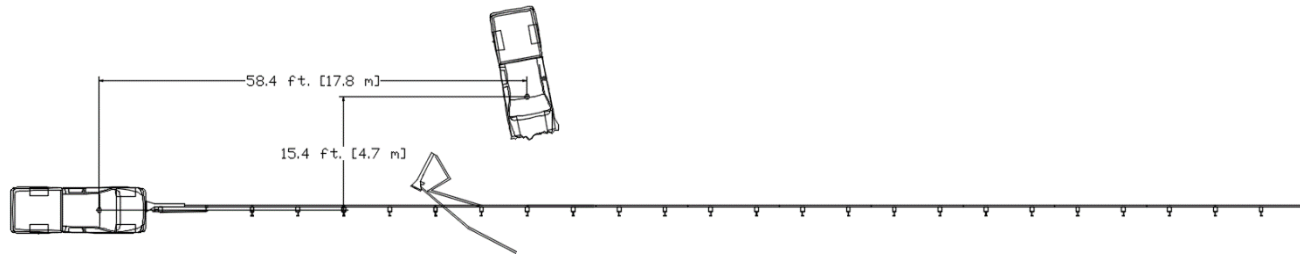
5.9 Discussion and Summary of Results

The SPIG Industries, LLC SGET end terminal met all the requirements for MASH 2016 Test 3-31. The system brought the vehicle to a controlled stop. None of the intrusion limits were exceeded, there was no penetration into the occupant compartment, and all the occupant risk factors were within the allowable limits. The SGET end terminal's performance to MASH 2016 test 3-31, was deemed as acceptable.

Table 8 Evaluation Criteria Summary

Evaluation Factor	Evaluation Criteria	Result						
Structural Adequacy	C Acceptable test article performance may be redirection, controlled penetration, or controlled stopping of the vehicle.	PASS						
Occupant Risk	D Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to other traffic, pedestrians, or personnel in a work zone.	PASS						
	F The vehicle should remain upright during and after the collision. The maximum roll and pitch angles are not to exceed 75°.	PASS						
	H Occupant impact velocities (OIV) should satisfy the following limits: <table border="1" data-bbox="402 1266 1317 1377"> <thead> <tr> <th>Component</th> <th>Preferred</th> <th>Maximum</th> </tr> </thead> <tbody> <tr> <td>Longitudinal and Lateral</td> <td>30 ft/s (9.1 m/s)</td> <td>40 ft/s (12.2 m/s)</td> </tr> </tbody> </table>	Component	Preferred	Maximum	Longitudinal and Lateral	30 ft/s (9.1 m/s)	40 ft/s (12.2 m/s)	PASS
	Component	Preferred	Maximum					
Longitudinal and Lateral	30 ft/s (9.1 m/s)	40 ft/s (12.2 m/s)						
I The occupant ridedown acceleration should satisfy the following limits: <table border="1" data-bbox="402 1451 1317 1562"> <thead> <tr> <th>Component</th> <th>Preferred</th> <th>Maximum</th> </tr> </thead> <tbody> <tr> <td>Longitudinal and Lateral</td> <td>15.0 g</td> <td>20.49 g</td> </tr> </tbody> </table>	Component	Preferred	Maximum	Longitudinal and Lateral	15.0 g	20.49 g	PASS	
Component	Preferred	Maximum						
Longitudinal and Lateral	15.0 g	20.49 g						
Vehicle Trajectory	N Vehicle trajectory behind the test article is acceptable.	PASS						
OVERALL TEST ASSESSMENT		PASS						

MASH 2016 Test 3-31 Summary



GENERAL INFORMATION	
Test Agency.....	KARCO Engineering, LLC.
KARCO Test No.....	P38108-01
Test Designation.....	3-31
Test Date.....	6/8/18
TEST ARTICLE	
Name / Model.....	SGET End Terminal
Type.....	End Terminal
Installation Length.....	156.3 ft. (47.6 m)
Terminal Length.....	50.0 ft. (15.2 m)
Road Surface.....	Medium to Fine Silty Soil
TEST VEHICLE	
Type / Designation.....	2270P
Year, Make, and Model....	2012 RAM 1500
Curb Mass.....	5,080.5 lbs (2,304.5 kg)
Test Inertial Mass.....	4,989.0 lbs (2,263.0 kg)
Gross Static Mass.....	4,989.0 lbs (2,263.0 kg)

Impact Conditions	
Impact Velocity.....	62.53 mph (100.63 km/h)
Impact Angle.....	0.6°
Location / Orientation.....	1.2 in. (30 mm) right of terminal CL
Kinetic Energy.....	652.1 kip-ft (884.1 kJ)
Exit Conditions	
Exit Velocity.....	N/A
Exit Angle.....	N/A
Final Vehicle Position.....	58.4 ft. (17.8 m) Downstream 15.4 ft. (4.7 m) Left
Exit Box Criteria Met.....	N/A
Vehicle Snagging.....	None
Vehicle Pocketing.....	None
Vehicle Stability.....	Satisfactory
Maximum Roll Angle.....	12.0 °
Maximum Pitch Angle.....	-6.4 °
Maximum Yaw Angle.....	-29.6 °

Occupant Risk	
Longitudinal OIV.....	18.4 ft/s (5.6 m/s)
Lateral OIV.....	1.3 ft/s (0.4 m/s)
Longitudinal RA.....	-6.0 g
Lateral RA.....	-4.4 g
THIV.....	18.7 ft/s (5.7 m/s)
PHD.....	6.0 g
ASI.....	0.54
Test Article Deflections	
Static.....	6.3 ft. (1.9 m)
Dynamic.....	7.6 ft. (2.3 m)
Working Width.....	7.6 ft. (2.3 m)
Debris Field.....	49.6 ft. (15.1 m) Downstream 18.2 ft. (5.5 m) Right
Vehicle Damage	
Vehicle Damage Scale.....	12-FR-3
CDC.....	12FZEW1
Maximum Intrusion.....	0.3 in. (8 mm)

Figure 2 Summary of Test 3-31

Appendix A

Photographs

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FIGURE 1. Test Setup



FIGURE 2. Test Setup, Close-Up



FIGURE 3. Test Setup



FIGURE 4. Test Setup, Close-Up



FIGURE 5. Test Setup



FIGURE 6. Test Setup, Close-Up



FIGURE 7. Test Setup



FIGURE 8. Test Setup, Close-Up



FIGURE 9. Test Setup



FIGURE 10. Test Setup, Close-Up



FIGURE 11. Pre-Test



FIGURE 12. Post-Test



FIGURE 13. Post-Test



FIGURE 14. Post-Test



FIGURE 15. Pre-Test Front View of Test Article



FIGURE 16. Post-Test Front View of Test Article



FIGURE 17. Pre-Test Right Front $\frac{3}{4}$ View of Test Article



FIGURE 18. Post-Test Right Front $\frac{3}{4}$ View of Test Article



FIGURE 19. Pre-Test Right View of Test Article



FIGURE 20. Post-Test Right View of Test Article



FIGURE 21. Pre-Test Right Rear $\frac{3}{4}$ View of Test Article



FIGURE 22. Post-Test Right Rear $\frac{3}{4}$ View of Test Article



FIGURE 23. Pre-Test Rear View of Test Article



FIGURE 24. Post-Test Rear View of Test Article



FIGURE 25. Pre-Test Left Rear $\frac{3}{4}$ View of Test Article



FIGURE 26. Post-Test Left Rear $\frac{3}{4}$ View of Test Article



FIGURE 27. Pre-Test Left View of Test Article



FIGURE 28. Post-Test Left View of Test Article



FIGURE 29. Pre-Test Left Front $\frac{3}{4}$ View of Test Article



FIGURE 30. Post-Test Left Front $\frac{3}{4}$ View of Test Article



FIGURE 31. Test Article Damage



FIGURE 32. Test Article Damage



FIGURE 33. Test Article Damage



FIGURE 34. Test Article Damage



FIGURE 35. Test Article Damage

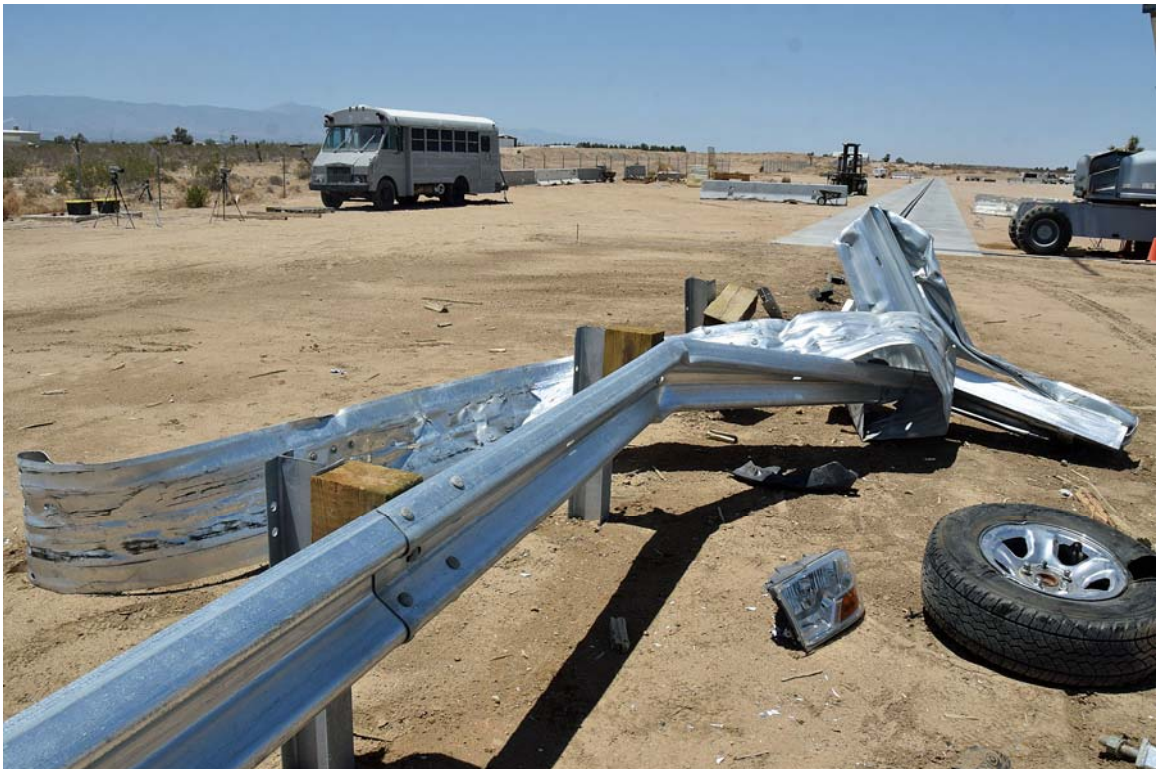


FIGURE 36. Test Article Damage



FIGURE 37. Pre-Test Left View of Test Vehicle



FIGURE 38. Post-Test Left View of Test Vehicle



FIGURE 39. Pre-Test Left Front $\frac{3}{4}$ View of Test Vehicle



FIGURE 40. Post-Test Left Front $\frac{3}{4}$ View of Test Vehicle



FIGURE 41. Pre-Test Front View of Test Vehicle

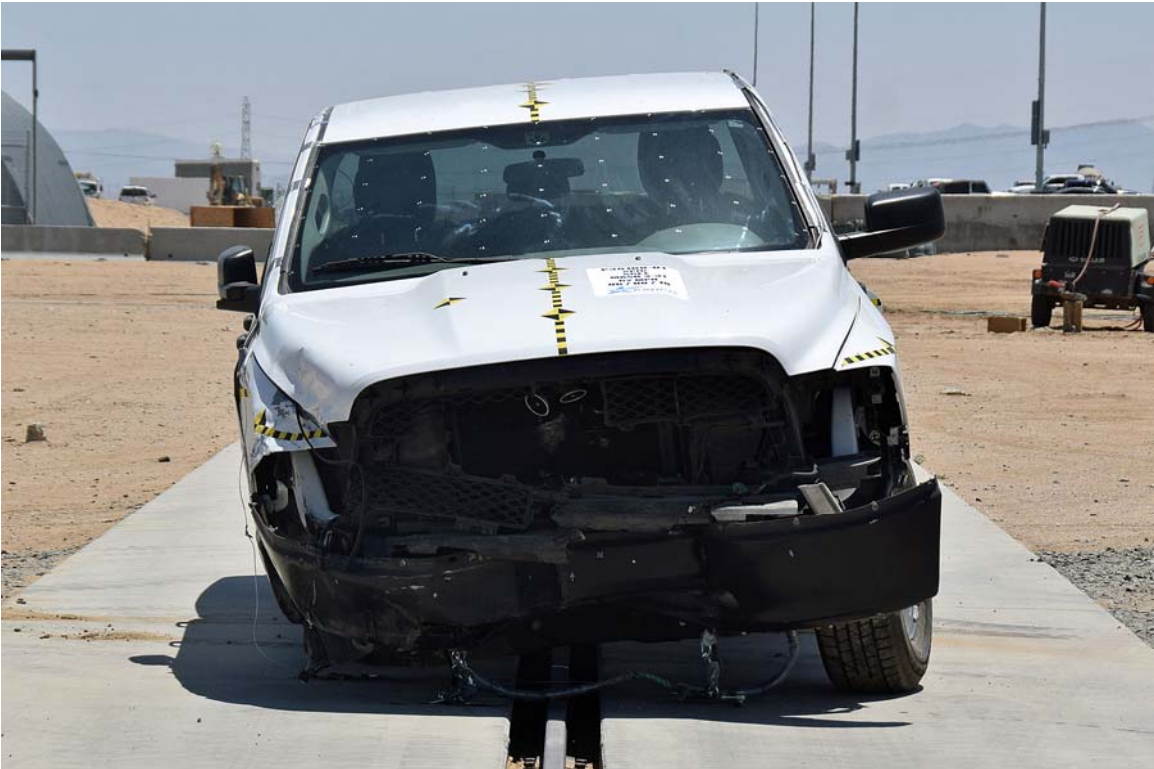


FIGURE 42. Post-Test Front View of Test Vehicle



FIGURE 43. Pre-Test Right Front 3/4 View of Test Vehicle

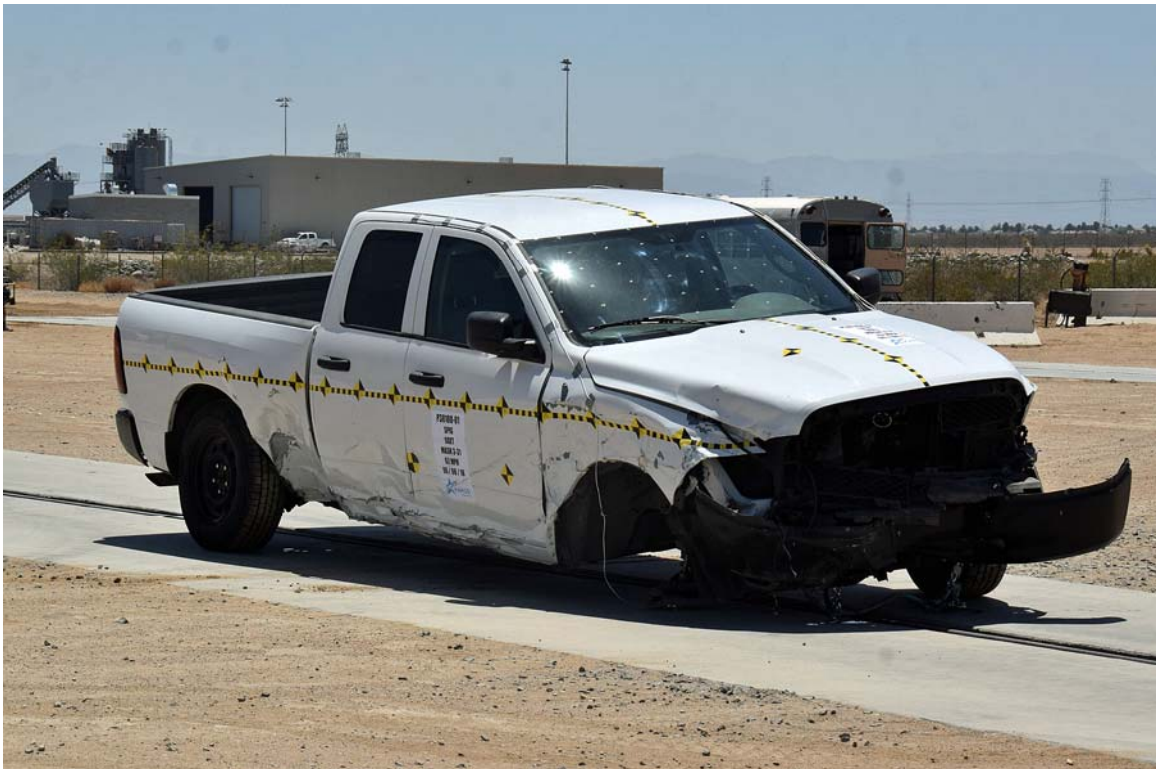


FIGURE 44. Post-Test Right Front 3/4 View of Test Vehicle



FIGURE 45. Pre-Test Right View of Test Vehicle



FIGURE 46. Post-Test Right View of Test Vehicle



FIGURE 47. Pre-Test Windshield



FIGURE 48. Post-Test Windshield



FIGURE 49. Pre-Test Driver Side Occupant Compartment



FIGURE 50. Post-Test Driver Side Occupant Compartment



FIGURE 51. Pre-Test Driver Side Floorpan



FIGURE 52. Post-Test Driver Side Floorpan



FIGURE 53. Pre-Test Passenger Side Occupant Compartment

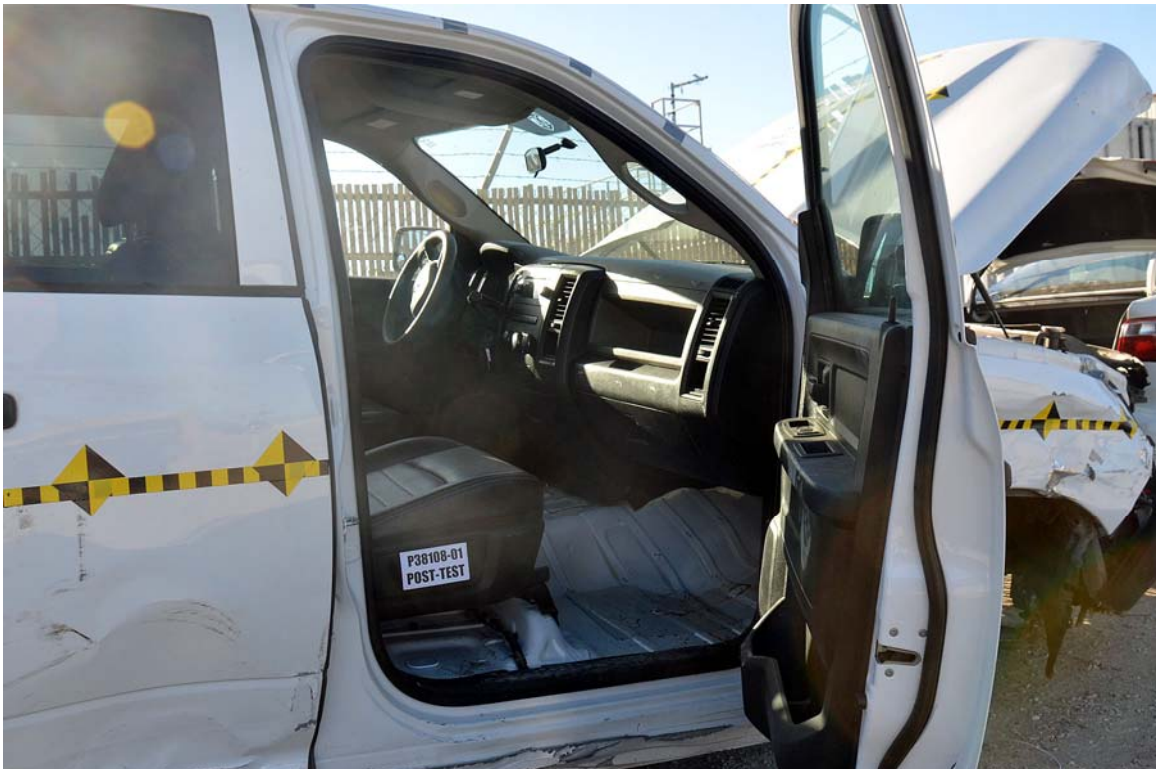


FIGURE 54. Post-Test Passenger Side Occupant Compartment



FIGURE 55. Pre-Test Passenger Side Floorpan



FIGURE 56. Post-Test Passenger Side Floorpan



FIGURE 57. Test Vehicle Manufacturer's Label

Appendix B

Data Plots

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10	Test Vehicle Accident Severity Index	B-3
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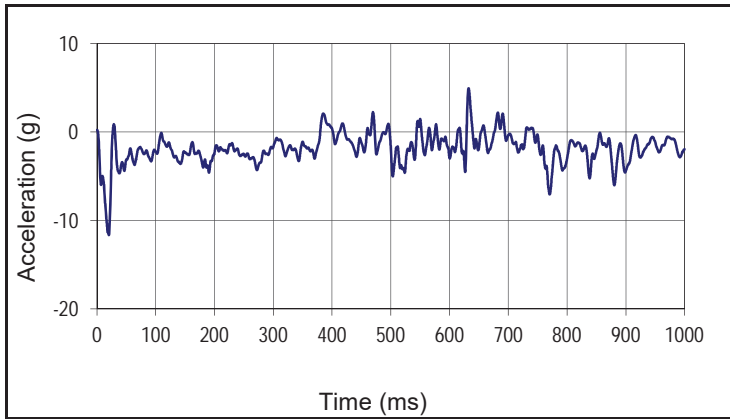
Appendix B
Data Plots

LIST OF DATA PLOTS

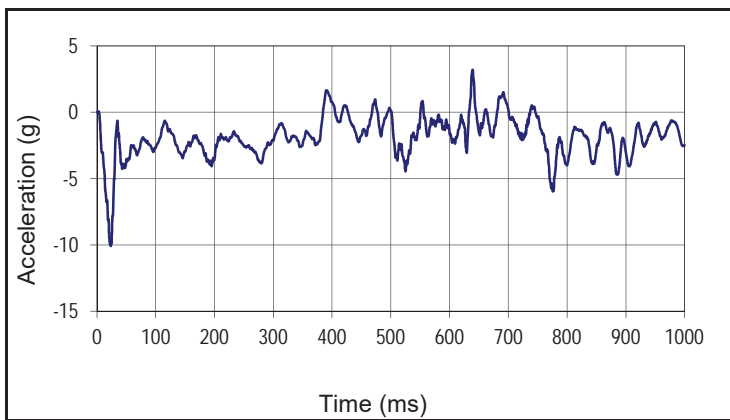
<u>Plot</u>		<u>Page</u>
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2	Test Vehicle CG X Moving Average	B-1
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11	Test Vehicle Roll Angle	B-4
12	Test Vehicle Yaw Angle	B-4
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Test Article: SPIG Industries SGET End Terminal
 Test Program: MASH 3-31

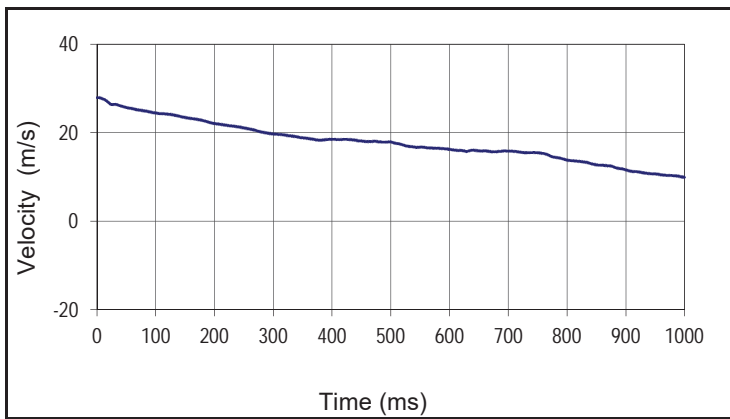
Project No: P38108-01
 Test Date.: 06/08/18



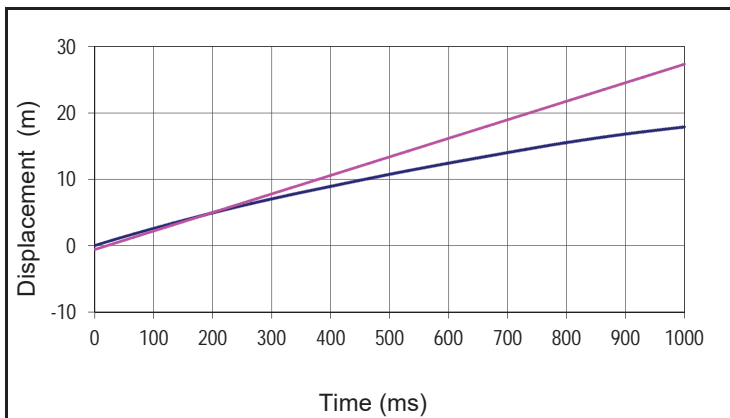
Curve Description			
Test Vehicle CG X			
Plot No.		SAE Class	Units
001		60	g
Max	Time	Min	Time
4.9	632.4	-11.6	20.3



Curve Description			
Test Vehicle CG X Moving Average			
Plot No.		SAE Class	Units
002		180	g
Max	Time	Min	Time
3.2	639.3	-10.1	23.5



Curve Description			
Test Vehicle CG X Velocity			
Plot No.		SAE Class	Units
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Max	Time	Min	Time
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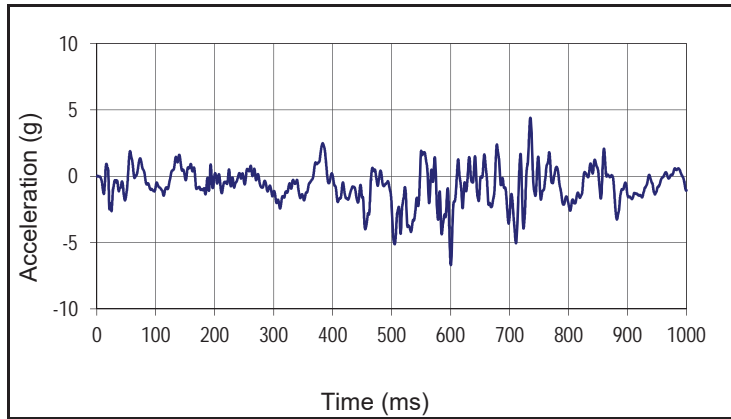


Curve Description			
Test Vehicle CG X Displacement			
Plot No.		SAE Class	Units
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Max	Time	Min	Time
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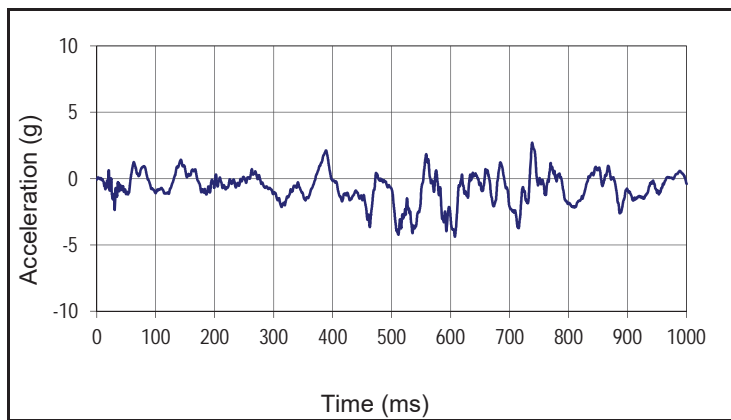
— Vehicle CG X Displacement
 — Occupant X Displacement

Test Article: SPIG Industries SGET End Terminal
 Test Program: MASH 3-31

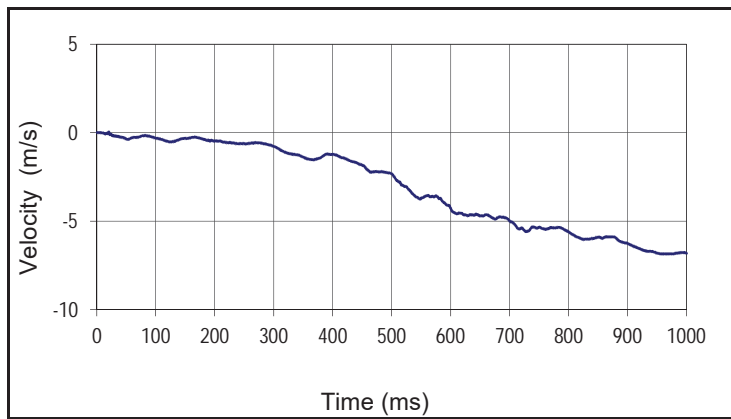
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 Test Date.: 06/08/18



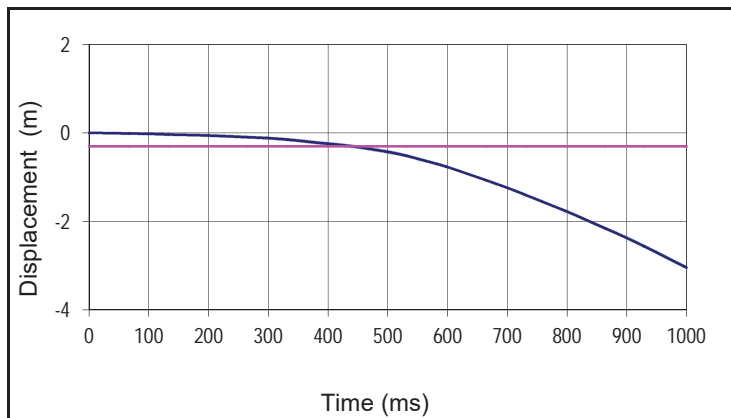
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Max	Time	Min	Time
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Curve Description			
Test Vehicle CG Y Moving Average			
Plot No.		SAE Class	Units
006		180	g
Max	Time	Min	Time
2.7	738.1	-4.4	607.2



Curve Description			
Test Vehicle CG Y Velocity			
Plot No.		SAE Class	Units
007		180	m/s
Max	Time	Min	Time
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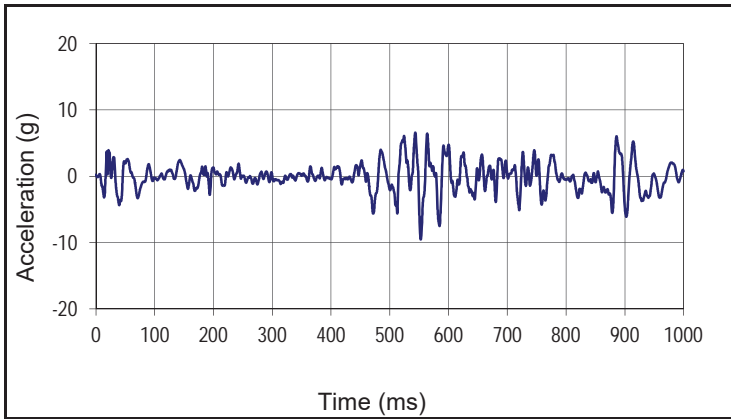


Curve Description			
Test Vehicle CG Y Displacement			
Plot No.		SAE Class	Units
008		180	m
Max	Time	Min	Time
0.0	7.2	-3.0	999.9

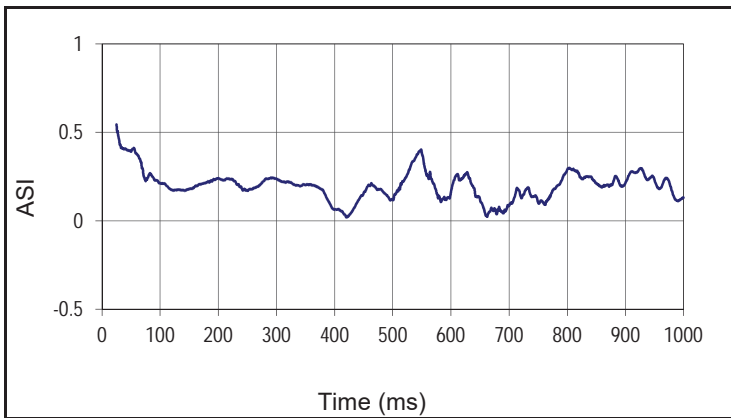
— Vehicle CG Y Displacement
 — Occupant Y Displacement

Test Article: SPIG Industries SGET End Terminal
 Test Program: MASH 3-31

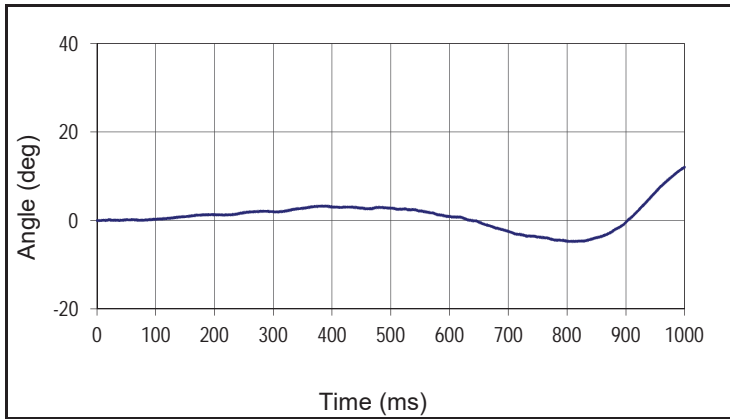
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 Test Date.: 06/08/18



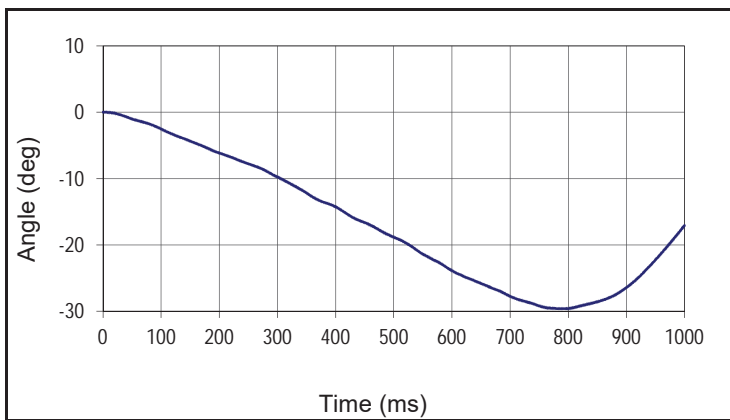
Curve Description			
Test Vehicle CG Z			
Plot No.		SAE Class	Units
009		60	g
Max	Time	Min	Time
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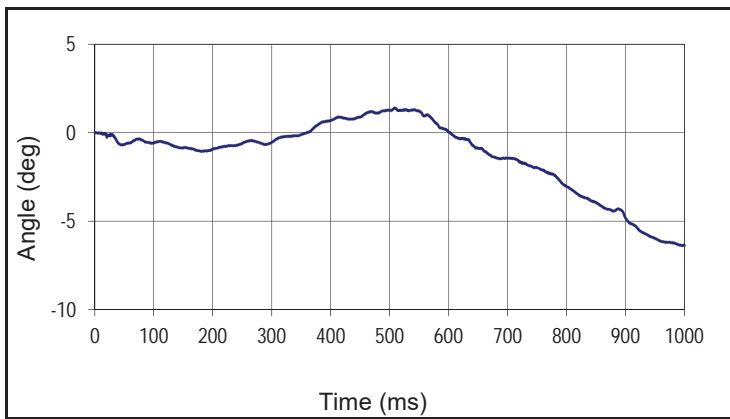
Curve Description			
Test Vehicle Accident Severity Index			
Plot No.		SAE Class	Units
010		180	ASI
Max	Time	Min	Time
0.5	25.0	0.0	420.0



Curve Description			
Test Vehicle Roll Angle			
Plot No.		SAE Class	Units
011		180	deg
Max	Time	Min	Time
12.0	999.9	-4.7	806.0



Curve Description			
Test Vehicle Yaw Angle			
Plot No.		SAE Class	Units
012		180	deg
Max	Time	Min	Time
0.0	3.0	-29.6	796.5



Curve Description			
Test Vehicle Pitch Angle			
Plot No.		SAE Class	Units
013		180	deg
Max	Time	Min	Time
1.4	508.5	-6.4	995.4

Appendix C
Soil Strength Information


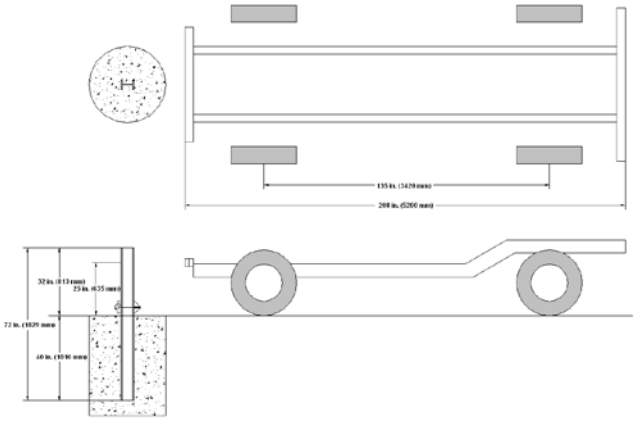

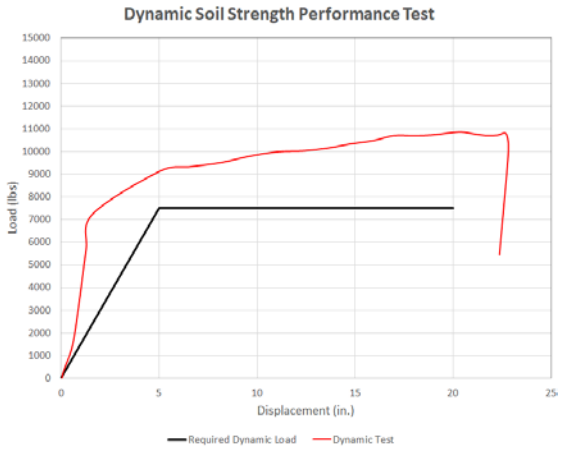
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2	Static Soil Strength Data	C-2
3	Soil Sieve Analysis	C-3

DYNAMIC SOIL STRENGTH DATA

Test Article: SPIG Industries SGET End Terminal Project No. P38108-01
 Test Program: MASH 3-31 Test Date: 06/08/18

DYNAMIC SOIL STRENGTH TEST DATA

	
Dynamic Test Setup	Dynamic Test/Installation Details
	
Post-Test Photo of Post	Comparison of Load vs. Displacement


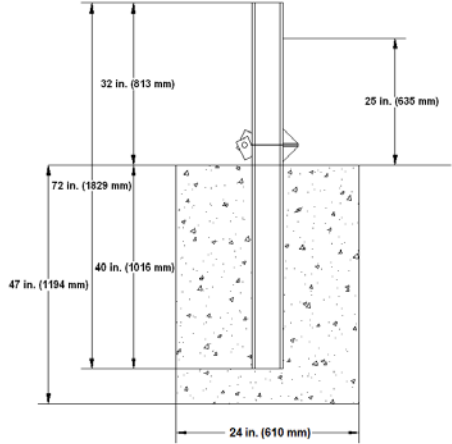

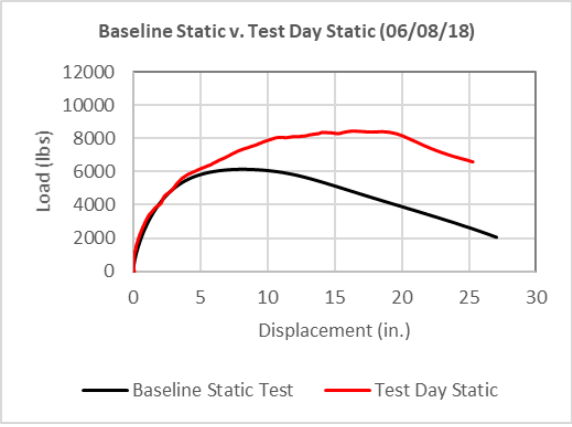
Certification Date	02/06/17
Test Facility and Site Location	KARCO, Track 4
In Situ Soil Description (ASTM D 2487)	Medium to fine silty sand
Description of Fill Placement Procedure	8.0 in. (203 mm) lifts compacted with pneumatic tamper
Bogie Weight	2,044.8 lbs (927.5 kg)
Impact Velocity	20.74 mph (33.38 km/h)

Figure 1: Dynamic Soil Strength Data

STATIC SOIL STRENGTH DATA

Test Article: SPIG Industries SGET End Terminal Project No. P38108-01
 Test Program: MASH 3-31 Test Date: 06/08/18

STATIC SOIL VERIFICATION TEST DATA

	
Static Load Test Setup	Static Test/Installation Details
	
Post-Test Photo of Post	Comparison of Load vs. Displacement

Date	06/08/18
Test Facility and Site Location	KARCO, Track 4
In Situ Soil Description (ASTM D 2487)	Medium to fine silty sand
Description of Fill Placement Procedure	8.0 in. (203 mm) lifts compacted with pneumatic tamper

Figure 2: Static Soil Strength Data

SOIL SIEVE ANALYSIS

Test Article: SPIG Industries SGET End Terminal

Project No. P38108-01

Test Program: MASH 3-31

Test Date: 06/08/18

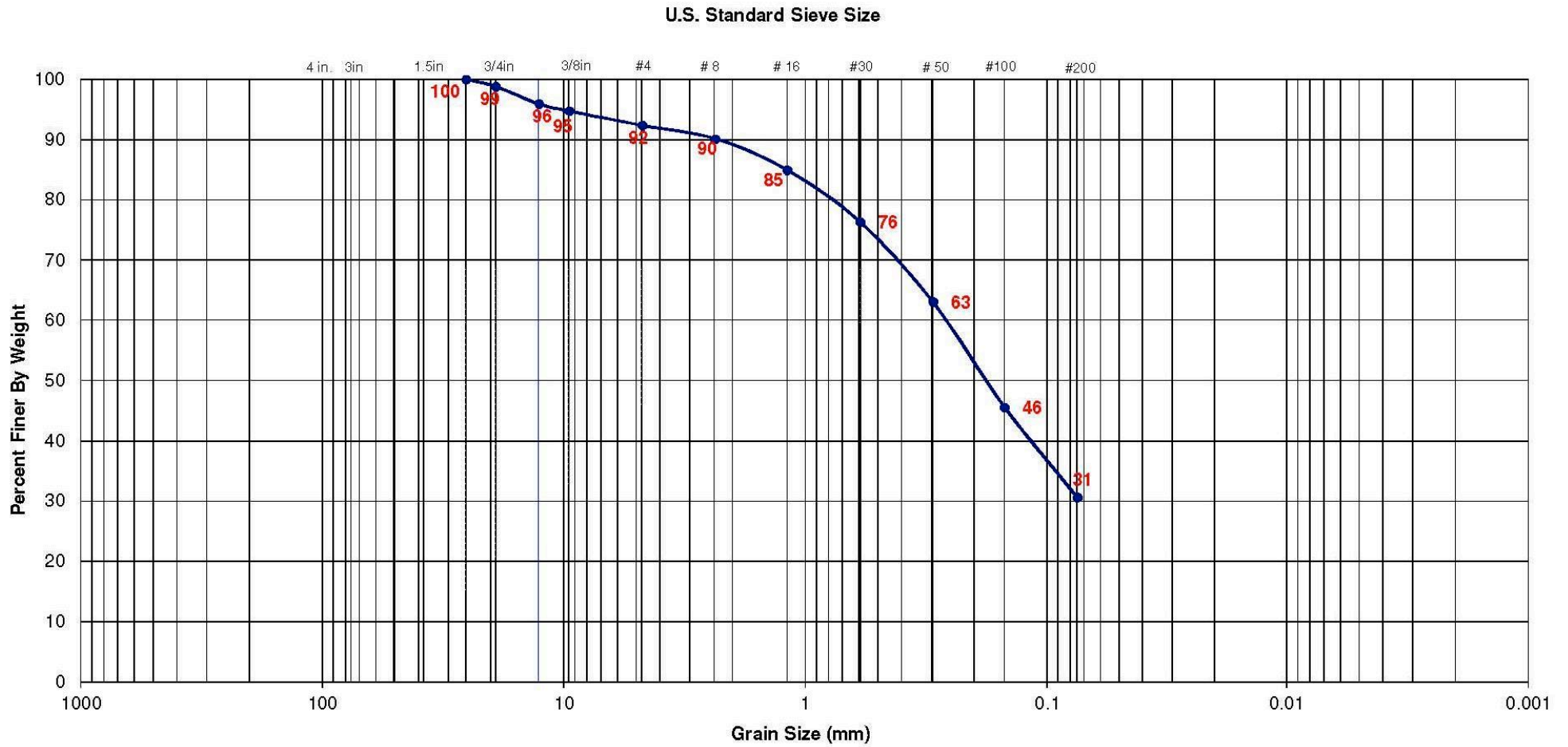


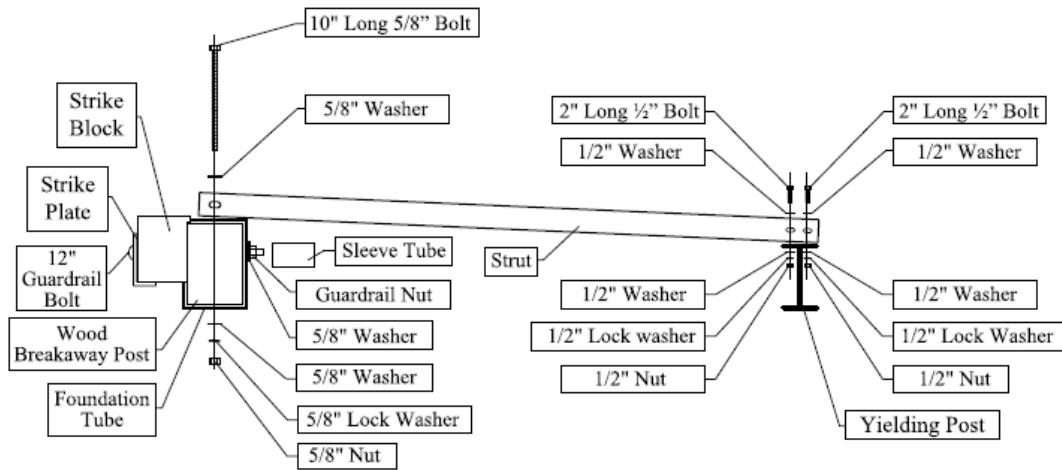
Figure 3: Soil Sieve Analysis

Appendix D
Manufacturer Documents

LIST OF FIGURES

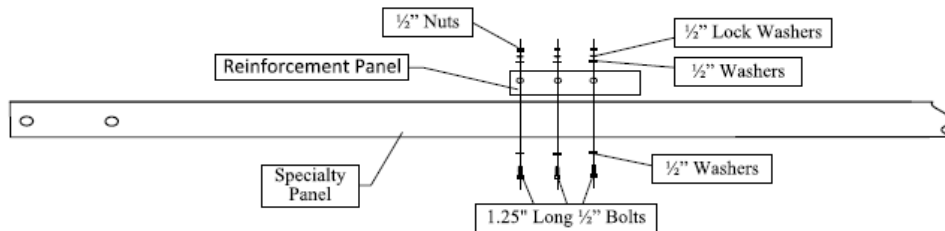
<u>Figure</u>		<u>Page</u>
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3	Single Guardrail Terminal	D-3
4	Single Guardrail Terminal	D-4

SGET SYSTEM PARTS



POST PARTS

PARTS	QTY
12" Guardrail Bolt – 5/8 X 12 307A HDG	1
Strike Plate	1
Strike Block	1
Guardrail Nut – 5/8-11 Nut A563 HDG	1
Wood Breakaway Post – 5-1/2 X 7-1/2 X 50 BCT	1
Foundation Tube – 6" X 8" X 6' Rectangular Tube	1
10" long 5/8" Bolt – 5/8-11 X 10 A325 HDG	1
5/8" Nut – 5/9-11 A563 Hex Nut Galvanized	1
5/8" Washer – 5/8 F436(A325) HDG Flatwasher	3
5/8" Lock Washer Galvanized	1
2" long 1/2" Bolt – 1/2-13 X 2 A325 HDG	2
1/2" Washer – 1/2 F436(A325) HDG Flatwasher	4
1/2" Nut – 1/2-13 A563 Hex Nut Galvanized	2
1/2" Lock Washer Galvanized	2
Yielding Post – Modified W6 X 8.5 Guardrail Post	7
Strut – 3" X 3" X 80" Angle	1
Sleeve Tube – 2-3/8 OD X 4-1/4	1

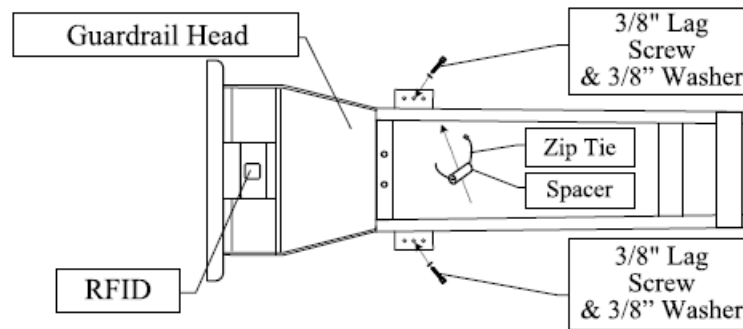


SPECIALTY PANEL PARTS

PARTS	QTY
Specialty Panel	1
1.25" Long 1/2" Bolt – 1/2-13 X 1-1/4 A325 HDG	6
1/2" Washer – 1/2 F436(A325) HDG Flatwasher	12
1/2" Nut – 1/2-13 A563 Hex Nut Galvanized	6
1/2" Lock Washer Galvanized	6
Reinforcement Plate	1

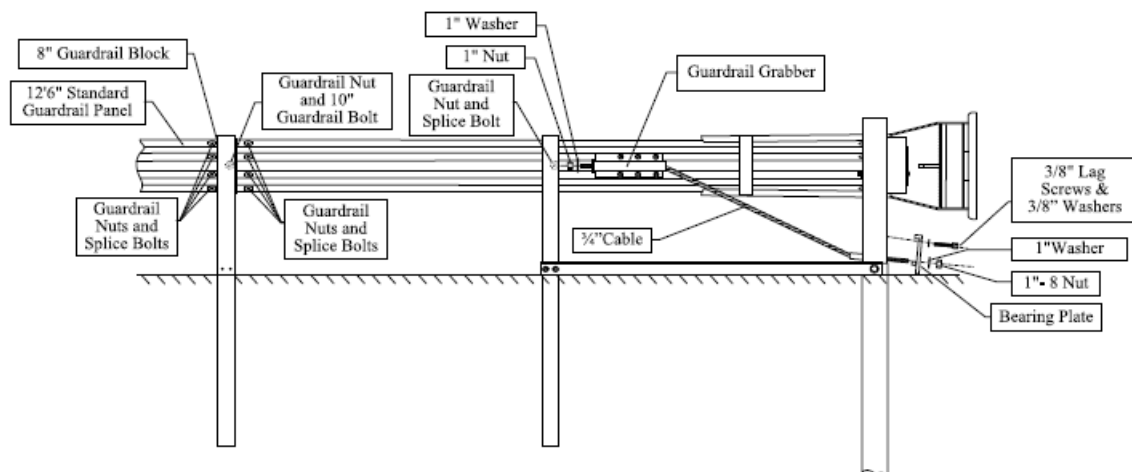
Figure 1: SGET System Parts

SGET SYSTEM PARTS



GUARDRAIL HEAD PARTS

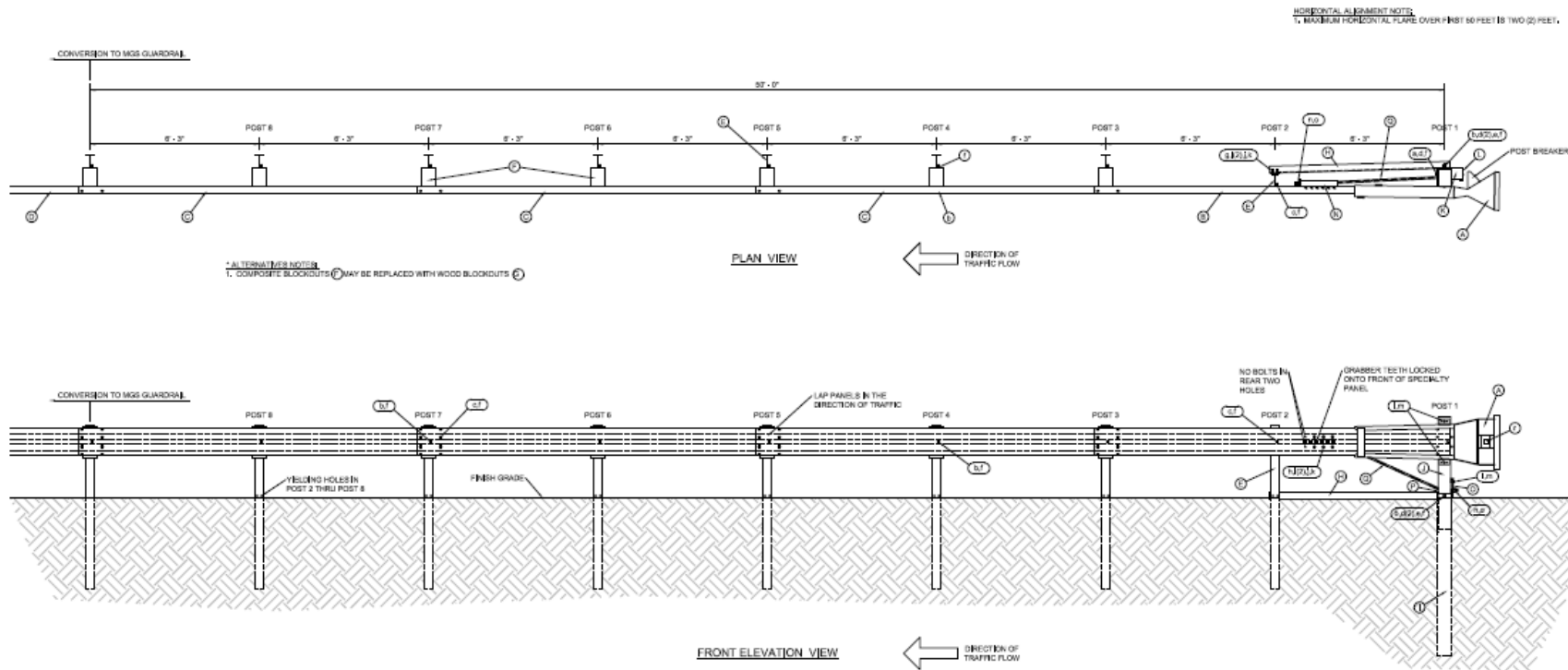
PARTS	QTY
Guardrail Head	1
3/8" Lag Screw – 3/8 X 3 GR5 HDG Hex Lag Screw	2
3/8" Washer Galvanized F844	2
Spacer – 4" Long X 1-1/2 SCH-40 PVC PIPE	1
Zip Tie – 18"-24" Long Rated at 175-200 lbs.	1
RFID chip rated MIL-STD-810F (e.g. Omni-ID EX0750)	1



RAIL AND CABLE PARTS

PARTS	QTY
3/4" Cable – 81" Long BCT Cable	1
1" Nut – 1- 8 Hex Nut UNC Galvanized A563DH	2
1" Washer Galvanized F436	2
Guardrail Splice Bolt – 5/8 X 1-1/4 307A HDG	25
10" Guardrail Bolt – 5/8 X 10 307A HDG	6
Guardrail Nut– 5/8-11 Nut A563 HDG	31
8" Guardrail Block	6
12' 6" Standard Guardrail Panel – W-Beam M-180	3
Bearing Plate	1
3/8" Lag Screw – 3/8 X 3 GR5 HDG Hex Lag Screw	2
3/8" Washer Galvanized F844	2
Guardrail Grabber	1

Figure 2: SGET System Parts



HORIZONTAL ALIGNMENT NOTES:
 1. MAXIMUM HORIZONTAL FLARE OVER POST IS TWO (2) FEET.

* ALTERNATIVES NOTES:
 1. COMPOSITE BLOCKOUTS (F) MAY BE REPLACED WITH WOOD BLOCKOUTS (G)

MAIN SYSTEM COMPONENTS

ITEM	QUANTITY	COMPONENT	ITEM NUMBER
A	1	SGET IMPACT HEAD	88HA
B	1	SPECIALIZED GUARDRAIL PANEL (MODIFIED 12' SECTION W-BEAM M-180)	1289P20P
C	3	STANDARD GUARDRAIL PANEL (12' SECTION W-BEAM M-180)	GP126
D	1	MGS CONVERSION GUARDRAIL PANEL (W-BEAM M-180)	GR26
E	7	YIELDING POST - MODIFIED W-BEAM GUARDRAIL POST	YPM00
F	6	COMPOSITE BLOCKOUT 8"x8"x4"	CR08
G	6	WOOD BLOCKOUT 8"x8"x4"	W08
H	1	STRUT - 2"x2"x8"x 1/2" A36 ANGLE	ST180
I	1	FOUNDATION TUBE - 8"x8"x12" 1/2" RECTANGULAR TUBE	FT018
J	1	WOOD BREAKAWAY POST - 4"x4"x7' 6"x4"	WBK40
K	1	WOOD STRIKE BLOCK	WSBK14
L	1	STRIKE PLATE - 2" A36 BENT PLATE	SP110
M	1	REINFORCEMENT PANEL - 12 GA. G355 17"x6.125" BENT PLATE	RP1717
N	1	GUARDRAIL GRABBER - 2 1/2"x2 1/2"x16 1/2" 3/4" A36 SQUARE TUBE	GR17
O	1	BEARING PLATE - 4"x6 3/8" 3/4" A36 PLATE	BPL16
P	1	PIPE SLEEVE - 4 1/2" LONG x 2 3/4" O.D. x 2 1/2" I.D. A36 ROUND TUBE	PSLV4
Q	1	3/4" CABLE - 61' LONG 3/4" B7C CABLE	CB181

SMALL HARDWARE

ITEM	QUANTITY	COMPONENT	ITEM NUMBER
a	1	14" GUARDRAIL BOLT - 3/8" x 12 307A HDG	14GBBLT
b	7	10" GUARDRAIL BOLT - 3/8" x 10 307A HDG	10GBBLT
c	33	1 1/2" GUARDRAIL SPRUCE BOLT - 3/8" x 1 1/2 307A HDG	1GBBLT
d	3	3/8" FLAT WASHER - 3/8" F436 (A325) HDG	58FW436
e	1	3/8" LOCK WASHER - HDG	58LW
f	36	3/8" HEX NUT - 3/8" x 11 A563 HDG	58HN563
g	2	2" STRUT BOLT - 1/2" x 13 x 2 A325 HDG	2BLT
h	6	1 1/2" REINFORCEMENT PANEL - 1/2" x 13 x 1 1/2 A325 HDG	12RBLT
i	16	3/4" FLAT WASHER - 3/4" F436 (A325) HDG	12FW436
j	3	3/8" LOCK WASHER - HDG	12LW
k	3	3/8" HEX NUT - 3/8" x 13 A563 HDG	12HN563
l	4	3/8" HEX LAG SCREW - 3/8" x 3 GR3 HDG	38LS
m	4	3/8" FLAT WASHER - 3/8" F436 HDG	38FW384
n	2	1" FLAT WASHER - 1" F436 (A325) HDG	1FW136
o	2	1" HEX NUT - 1" x 8 A563 HDG	1HN563
p	1	RATED 40K RATED M16x10x10F (2x, 0.5MM) EX2750	87CE107

THIS PLAN IS NOT FINAL, UPON APPROVAL MY SEAL AND DATED SIGNATURE WILL APPEAR WHERE THIS CIRCLE EXISTS.

CERTIFICATION STATEMENT:
 I, BARNEY HORRELL, DO HEREBY CERTIFY THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER IN THE STATE OF VIRGINIA, LICENSE NO. 6622044854 AND THAT I PERSONALLY DRAFTED THIS PLAN SHEET BASED ON SKETCHES AND INFORMATION PROVIDED BY THE MANUFACTURER. I DO NOT CERTIFY TO THE DESIGN OR EFFECTIVENESS OF ANY OF THE ITEMS SHOWN. THE MANUFACTURER HAS COMMISSIONED OTHER PROPERLY LICENSED INDEPENDENT FIRMS TO TEST AND CERTIFY TO THE EFFECTIVENESS OF THE ITEMS AND THEIR CONFIGURATION DEPICTED HEREON. THIS STATEMENT AND THE SEAL ABOVE REPRESENT ONLY THAT THIS DRAWING IS AN ACCURATE GRAPHIC DEPICTION OF THE INFORMATION PROVIDED TO ME BY THE MANUFACTURER.

CALIFORNIA DEPT. OF TRANSPORTATION (CALTRANS)

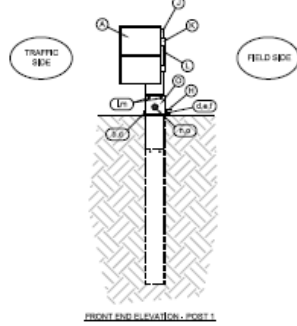
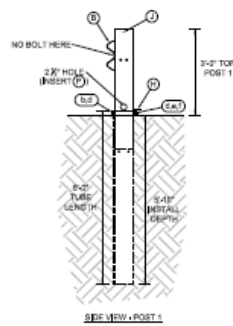
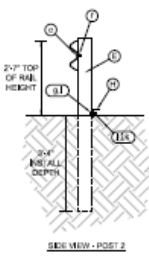
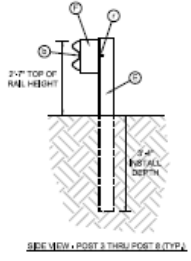
SINGLE GUARDRAIL TERMINAL

SGET-MASH-TL-3

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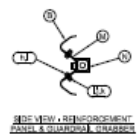
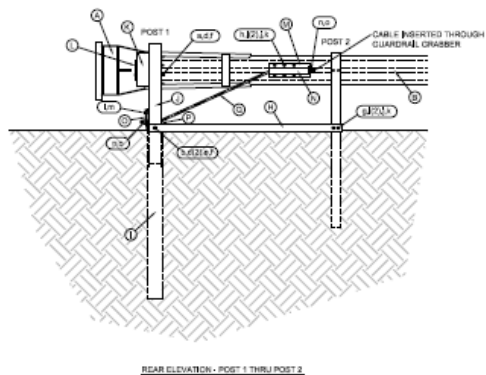
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Figure 3: Single Guardrail Terminal



GENERAL NOTES:

1. STEP-BY-STEP INSTALLATION INSTRUCTIONS AS WELL AS OTHER GUIDANCE ARE AVAILABLE FROM SPIG INDUSTRY, INC., (276) 844-6510, 14675 INDUSTRIAL PARK RD., BRISTOL, VA 24202.
2. THE FIRST SPECIALIZED GUARDRAIL PANEL SHOULD BE CENTERED BETWEEN THE MOUNTING TABS OF THE SGET IMPACT HEAD SUCH THAT THE TOP SPACING BETWEEN THE TOP OF THE FIRST SPECIALIZED GUARDRAIL PANEL AND THE TOP FEED CHANNEL OF THE SGET IMPACT HEAD IS THE SAME AS THE BOTTOM SPACING BETWEEN THE BOTTOM OF THE FIRST SPECIALIZED GUARDRAIL PANEL AND THE BOTTOM FEED CHANNEL OF THE SGET IMPACT HEAD. A PLASTIC SPACER IS PROVIDED WITH THE INSTALLATION KIT TO ACCOMPLISH THE CENTERING OF FIRST SPECIALIZED GUARDRAIL PANEL BETWEEN THE MOUNTING TABS OF THE SGET IMPACT HEAD.
3. THE CABLE SHOULD BE TENSIONED SUCH THAT LESS THAN 1 INCH OF DEFLECTION OCCURS WHEN THE CABLE IS STEPPED ON.
4. THE THREADED END OF THE CABLE SHOULD ONLY PROTRUDE 1 TO 1 1/2 INCH FROM THE CABLE TIGHTENING NUT AT THE END OF THE GUARDRAIL GRABBER (N) ON THE FIRST SPECIALIZED GUARDRAIL PANEL (S).
5. THE NOMINAL HEIGHT OF THE GUARDRAIL BEAM IS 31 INCHES WITH A TOLERANCE OF +/- ONE INCH.
6. THE ENTIRE SYSTEM MUST BE INSTALLED IN A STRAIGHT LINE WITHOUT ANY CURVE. HOWEVER, THE SYSTEM CAN BE FLARED UP TO TWO FEET OVER 50 FEET TO FURTHER OFFSET THE FACEPLATE OF THE SGET IMPACT HEAD FROM THE SHOULDER OF THE ROAD.
7. THE SYSTEM IS SHOWN WITH A FIRST 12'-6" SPECIALIZED GUARDRAIL PANEL, A SECOND 12'-6" STANDARD GUARDRAIL PANEL, A THIRD 12'-6" STANDARD GUARDRAIL PANEL, AND A FOURTH 12'-6" STANDARD GUARDRAIL PANEL. THE FIRST 12'-6" SPECIALIZED PANEL MUST ALWAYS BE USED.
8. POSTS 2 THROUGH 8 MUST ALL BE YIELDING POSTS WITH THE YIELDING HOLES AT GROUND LEVEL.
9. THE REFLECTIVE CAPABILITY OF THE SYSTEM BEGINS AT POST 3.



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CALIFORNIA DEPT. OF TRANSPORTATION (CALTRANS)
SINGLE GUARDRAIL TERMINAL
SGET-MASH-TL-3

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	##	##		2 OF 2

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FILE: SGET_201_06_T210W0

Figure 4: Single Guardrail Terminal

Appendix E
Sequential Photographs

Appendix E
Sequential Photographs



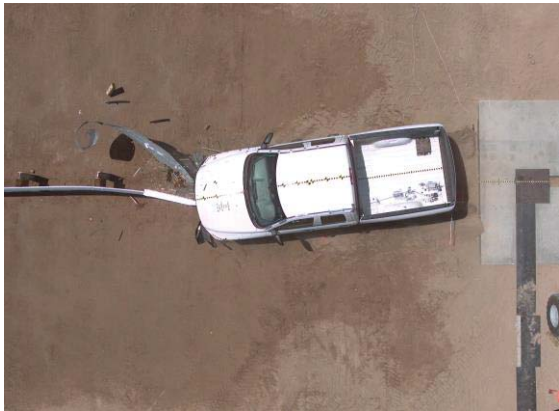
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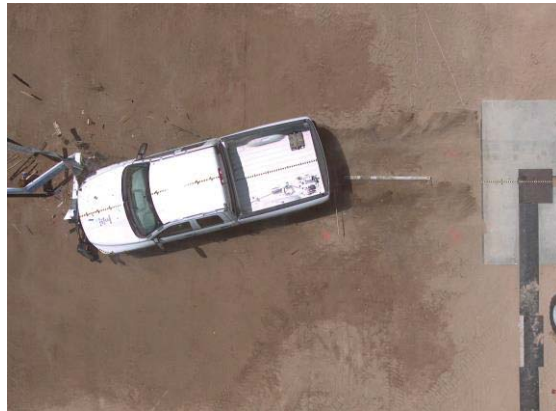
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Appendix F

References

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